Waterborne Disease - USA

Number of Drinking Water Outbreaks, 1991 - 2000

Number of Cases of Illness Due to Drinking Water Outbreaks, 1991 - 2000

Waterborne Disease – Global Statistics

- 1.1 billion people lack access to improved water supply
- 2.6 billion people lack access to improved sanitation
- Between 1.085 to 2.187 million deaths each year due to diarrheal diseases can be attributed to the ‘water, sanitation, and hygiene’ risk factor
  - 90% of these deaths are among children under age 5
LEGEND  Proportion of the population using improved drinking water sources, total

- 100%
- 90% - 99%
- 70% - 89%
- 50% - 69%
- Less than 50%
- No data

* disclaimer
Burden of Waterborne Disease

- Water-related disease is the 2\textsuperscript{nd} biggest killer of children worldwide (1\textsuperscript{st} = acute respiratory infections)

- At any one time:
  - half of the world’s hospital beds are occupied by patients suffering from water-related diseases (WaterAid, 2008)
  - half of the population of the developing world is suffering from one or more diseases associated with inadequate water and sanitation (WaterAid, 2008)
Burden of Waterborne Disease

• 443 million school days lost annually to water-related diseases

  • to reduce by half the proportion of people without access to safe water and sanitation by 2015
  • An extra $10 billion needed each year to reach the goal (this is about half of what rich countries spend on mineral water)
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*Ultimate goal*: Prevention of waterborne disease

- **Water treatment technologies**
  - Chlorination (SWS)
  - Ceramic filtration
  - Biosand filtration

- **Watershed management**
  - Parasite source tracking (Cryptosporidium)
  - Parasite fate and transport
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**Ultimate goal:** Prevention of waterborne disease

**Water treatment technologies**
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Safe Water System (SWS)

- Strategy devised by CDC and PAHO to reduce waterborne diarrheal disease
- Three components to SWS
  - Water treatment with dilute sodium hypochlorite
  - Storage of water in a safe container
  - Education to improve hygiene and water and food handling processes
Safe Water System (SWS)

- Sodium hypochlorite (= dilute chlorine bleach)
  - Particles in water will bind to chlorine, reducing the amount of chlorine that is available to disinfect microorganisms
  - By removing particles in water before disinfecting with chlorine, a smaller dose of chlorine can be used to achieve effective disinfection
    - Fewer taste and odor issues
    - Saves money (a bottle of chlorine solution will last longer)
Safe Water System (SWS)

- Jellison lab undergraduate research project with the U.S. Centers for Disease Control
  - Evaluate water pretreatment methods for the potential to
    (i) remove particulates
    (ii) reduce the amount of sodium hypochlorite solution necessary to maintain a safe disinfection residual
  - Current SWS recommendations: add single capful of SWS solution per 20 L water (add two capfuls per 20 L for turbid water)
Safe Water System (SWS)

- Some common water pretreatment methods
  - Physical pretreatment
    - Cloth filtration
    - Sand filtration
    - Settling/Decanting
Safe Water System (SWS)

- Some common water pretreatment methods
  - Chemical pretreatment
    - Coagulants – alum, moringa seeds
Safe Water System (SWS) - Conclusions

- Turbidity reduction
  - all five clarification methods were effective
- Chlorine demand reduction/maintaining safe chlorine residual at 24 hrs
  - Sand filtration, settling & decanting, and alum coagulation were effective across all turbidity levels
  - Cloth filtration and moringa coagulation were not effective
Safe Water System - Recommendations

- Recommended sodium hypochlorite dosages after pre-treatment of the source water:
  - After sand filtration = 1.875 mg/L (single capful)
  - After settling/decanting = 1.875 mg/L (single capful)
    - 24 hr settling time recommended
  - After cloth filtration = 3.75 mg/L (double capful)
  - After alum coagulation = 1.875 mg/L (single capful)

- Using raw moringa seeds for pre-treatment before chlorine is no longer recommended
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Water treatment technologies (emphasis on developing countries)
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Ceramic Filtration

- Potters for Peace filter
  - 2 separate parts: (i) ceramic pot and (ii) plastic container that the pot sits inside
  - Ceramic pot has colloidal silver coating (germicide)
  - Ceramic has very small pores which entrap contaminants as water passes through
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Biosand Filtration

- Dimensions: 0.3m x 0.3m x 0.9m
- Weight: 170 lbs.
- Costs: $10-45 USD
Biosand Filtration

2 L Pitcher Filter
Biosand Filtration
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Cryptosporidium
Cryptosporidium Life Cycle

(Adapted from Current & Blagburn, 1990)
Methods

Surface Water Filtration

Immunomagnetic Separation

DNA Extraction

Nested PCR

Clone & Sequence

Phylogenetic Analysis

Fecal Sample Collection
Wissahickon Creek Watershed

(From: National Institute for Environmental Renewal, 1999)
Wissahickon Creek, May 2005 - April 2006

- Genotypes Not Associated with Human Disease (33%)
  - Goose (n=1)
  - Snake (n=2)
  - Deer Mouse (n=3)

- Other Genotypes Associated with Human Disease (33%)
  - Cervine (n=3)
  - Skunk (n=5)

- Human Pathogens (34%)
  - C. hominis (n=6)

n=18

Wissahickon Creek, May 2006 - April 2007

- Genotypes Not Associated with Human Disease (33%)
  - Goose (n=1)
  - Deer Mouse (n=1)
  - Other (n=2)

- Human Pathogens (34%)
  - C. hominis (n=1)
  - C. pansum (n=3)

- Other Genotypes Associated with Human Disease (33%)
  - Cervine (n=3)
  - Skunk (n=1)

n=12

Wissahickon Creek, May 2007 - April 2008

- Genotypes Not Associated with Human Disease (37.5%)
  - Goose (n=1)
  - Chipmunk (n=1)
  - Mink (n=1)
  - Other (n=1)

- Human Pathogens (25%)
  - C. hominis (n=4)

- Other Genotypes Associated with Human Disease (37.5%)
  - Cervine (n=2)
  - Skunk (n=2)

n=16
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**Ultimate goal:** Prevention of waterborne disease

**Water treatment technologies**
( emphasis on developing countries )
- Chlorination (SWS)
- Ceramic filtration
- Biosand filtration

**Watershed management**
- Parasite source tracking
  (Cryptosporidium)
- Parasite fate and transport
Grazing:
UV Exposure

Artificial UV-B Exposure

% Infectivity (Adjusted)

- Dark Control
- 48% UVB
- 100% UVB
UV Exposure

Solar Exposure

% Infectivity (Adjusted)

- Dark Control
- 48% solar
- 100% solar

15-Jul
16-Jul
UV Exposure

Solar Exposure +/- UV

% Infectivity (Adjusted)

Dark Control
Full Solar
Solar (- UV)

7-Sep
10-Sep
Cryptosporidium and Biofilms
\[ R = \frac{1}{N} \sum_{i=1}^{N} \frac{|L_{fi} - \bar{L}_f|}{L_f} \]

where \( \bar{L}_f \) is the mean thickness, \( L_{fi} \) is the \( i \)th individual thickness, and \( N \) is the number of thickness measurements.
The figure shows the percentage distribution of oocysts in two different conditions: Lab Stock and Biofilm.

- **Lab Stock**:
  - % DAP I+/P I- (intact): 62%
  - % DAP I-/P I- (broken): 12%
  - % DAP I+/P I+: 20%

- **Biofilm**:
  - % DAP I+/P I- (intact): 56%
  - % DAP I-/P I- (broken): 20%
  - % DAP I+/P I+: 20%

The percentage distribution is visually represented in the bar chart, with different colors indicating each condition.
Biofilms as Biomonitors
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<th>Biofilm FISH</th>
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<th>Water Sample PCR</th>
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Summary

Ultimate goal: reduce prevalence of waterborne disease

- Understand parasite fate and transport in the environment
- Identify public health risk associated with parasites in drinking water supplies
- Improve methods for watershed monitoring of parasites
- Optimize household water treatment options in developing countries and develop standard operating procedures for their use
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Questions?
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